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Organic Evolution and the Capability Maturity of Business Intelligence

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ABSTRACT

With the emergence of a new form of competition based on the extensive use of analytics, data, and subsequent decision-making, business intelligence (BI) has become a dominant platform for delivering solutions. The notion of gaining and sustaining competitive advantage through the use of complex analysis and data-intensive technologies has changed the way organizations manage themselves and compete in the marketplace. Initially, similar to other strategic technologies, BI will evolve or change depending on organizational needs and maturity. This suggests that process-oriented, descriptive, maturity models like the Capability Maturity Model apply. Despite the significance of BI, little attention has been given to examining the natural progression of business intelligence adoption and maturation within organizations. This is a concept paper presenting a model describing the relationship between evolution and the levels described by capability maturity. The proposed conceptual model is illustrated through the examination of a large, national, non-profit organization.

Keywords

Business intelligence, capability maturity, adoption of information technology

INTRODUCTION

Business intelligence (BI) has emerged as a contemporary methodology for knowledge discovery and utilization within many enterprises. The purpose of business intelligence is the reduction of uncertainty and provision of support for better decisions making. Promising the capability to deliver insight into the strengths and weakness of the organization, opportunities and threats in the market, and even forecast unforeseen future events, business intelligence has emerged as the dominant extension of knowledge data discovery. The attractiveness of this promise has driven many organizations, large and small, to enter the business intelligence arena, with a range of technologies and tools accelerating the adoption of the methodology.

Built on the data warehouse platform, BI inherits all of the challenges of those projects, in addition to extenuating factors in BI usage. Similarly BI incorporates facets of many classic information systems. BI includes functionality that is often seen as defining characteristics of classic information systems such as: management information systems (MIS), decision support systems (DSS), expert systems (ES), and executive information systems (EIS) (Figure 1.)

From this perspective BI may be viewed as an umbrella technology that spans the capability, functionality, and architecture of these other information systems; the threading concept being support for organizational

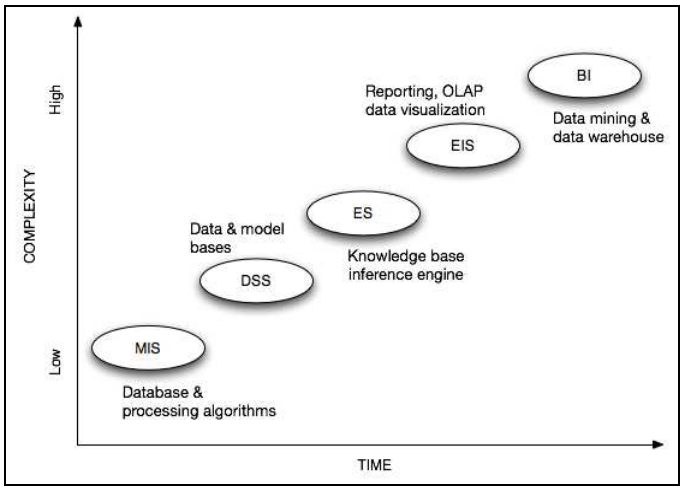

Figure 1: Development of management information systems (Olszak & Ziemba, 2004)

decision-making. However, BI differs from these other systems in its wider thematic range, multivariate analysis, semi-structured data originating from different sources and multidimensional data presentation (Watson & Gray, 1997). If BI consolidates, integrates, and delivers similar capability with an increased scope, it may suffer from the same development, deployment, and operational challenges that characterized its predecessors. Further, given the technologies and architectures on which BI is built, implementations are an ongoing activity even after the initial deployment. For example the data warehouse will continue to be extended or modified as the system traverses the normal life cycle. Similarly, as organizational needs and requirements shift, the expectations and necessary support from the BI platform will also continue to change. The functional activities involved in a BI implementation continue long after deployment (Burton & McDonald, 2006; Howson, 2008). The natural development of information system implies that business intelligence is not yet the final step for decisions support technologies. Applying an evolutionary analogy suggests a recursive model of change and progress that may be characterized at its foundational level as maturity. Few models have been proposed that describe the maturation of business intelligence and they emphasize usage or activities as the organization matures in its application of the underlying business intelligence technologies. These models propose that organizations march sequentially through time; maturing at each step or level, defined by increased qualitative or quantitative capability changes ultimately culminating in some final "mature" state.

The conceptual model in this paper proposes that there is an "evolutionary" process in which business intelligence maturity phases exist. Generalizing this concept implies that maturity may be an indicator of proximity to evolutionary shifts. The model proposes that the individual steps characterizing capability maturity occur sequentially and potentially recursively within a macro environment of evolution that is triggered by significant social, environmental, or technological shifts or changes within or around the organization. The paper is organized as follows. Section 2 discusses background on existing business intelligence maturity models and the CMMI capability maturity model. Section 3 presents the conception model and characterizes how the capability maturity model fits. Section 4 illustrates the evolutionary-maturity model through the characterization of a national non-profit organization's business intelligence implementation and operation. Finally, the paper is concluded with a discussion of the concepts implications and potential future work.

BACKGROUND

The notion of maturity is a frequently used concept to describe the advancement of both people and organization. The prevailing idea is that maturity is a somewhat linear, forward moving (perhaps with some opportunity to regress), process in which the object, person, or organization of consideration improves relative to quantitative or qualitative capabilities. The underlying precept is that a higher degree of maturity indicates increased change in several dimensions including formality, commitment, consistency, understandability, and competence in the context of a maturing element.

This general definition of maturity has demonstrated utility when applied to concepts of varying granularity from technology, to organizations, to processes. In the context of business intelligence, maturity is defined by knowledge derivation and dissemination, decision-making, competitive differentiation, and value creation capabilities. These capabilities tend to be the emphasis of business intelligence maturity models proposed in the literature. The available maturity models for BI intelligence maturity are sparse, with most being developed by industry practitioners. Models put forth in the domain include Logica's Capability/Maturity Model (C/M) (Van Roekel et al., 2009). Gartner's Business Intelligence and Performance Management Maturity Model (BIPMM) (Hostmann, 2007), and The Data Warehouse Institute's (TDWI) business intelligence model (Eckerson, 2007). Examination of these models reveals a heavy practical orientation and emphasis on functional capabilities (reporting, data warehouses, and predictive analytics).

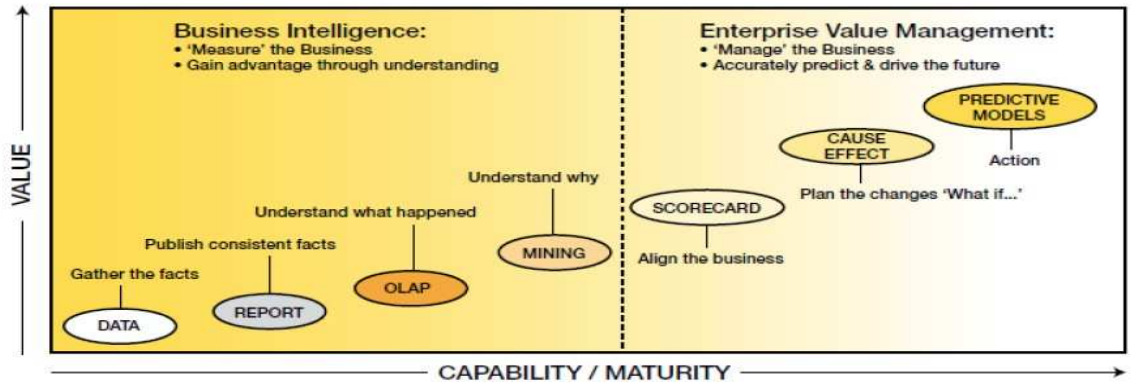

Figure 2: Logica's Capability/Maturity Model (C/M) (Van Roekel, Linders, Raja, Reboullet, & Ommerborn, 2009)

Logica's model (Figure 2) clearly illustrates the technical details as a definition of capability. While C/M separates capability from enterprise maturity the implication is that business intelligence feeds into enterprise value as functional technical capability matures. Moreover the linear nature of maturation is concisely defined based on the need to move through each step. Gartner's model (Figure 3) takes a different approach, instead focusing on organizational change. The model proposes that as an organization's business intelligence and performance management changes over time it will mature based on the defined levels. While BIPMM characterizes maturity based on organizational characteristics to a higher degree than functional technology capability, it suggests that there is finality to maturity that would occur in Level 5. To further illustrate this point, Hostmann's (2007) research concluded that 89% of organizations are at either the tactical or focused level of maturity; 7% at level four and none at level five.

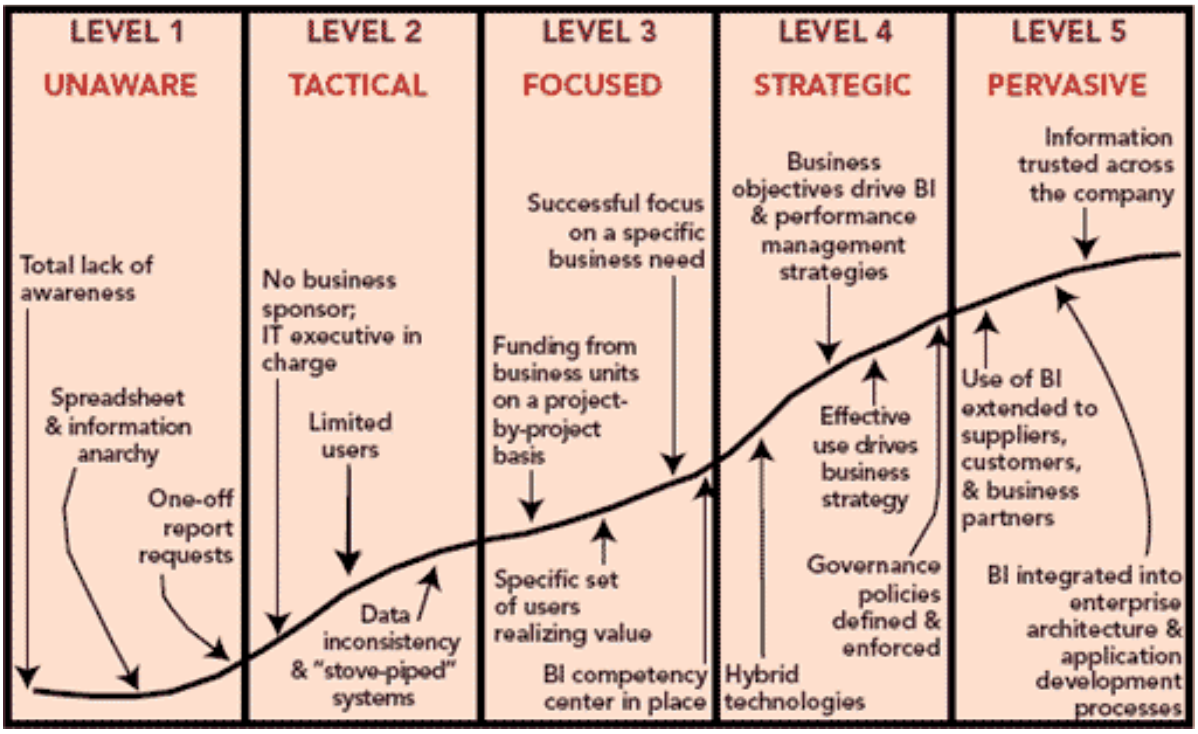

Figure 3: Gartner's Business Intelligence and Performance Management Maturity Model (BIPMM) (Hostmann, 2007)

The TDWI business intelligence maturity model (Figure 4) combines the contributions of C/M and BIPMM into an integrated model. The TDWI model consists of six stages from infancy (traditional management reporting and spreadsheets) to adulthood and sage (enterprise data warehousing and analytical services). It is noteworthy that the TDWI model finds it grounding in the Capability Maturity Model Institute's (CMMI) capability maturity model. TDWI incorporates business value and organizational change in their model and simplifies its understanding by with human maturity analogies. TDWI's model also explains that no organization progresses through the six stages at the same rate and many exhibit characteristics of multiple stages at the same time. The model also illustrates that most organizations are in the child-teenager phase, underscoring the temporally finite nature of the model.

There are other business intelligence maturity models (Chamoni & Gluchowski, 2004; Popovič, Coelho, & Jaklič, 2009; Williams & Williams, 2007)but these models are similar in detail to industry models taking a different orientations on the measure of maturity such as quality or profit, rather than capability. The prevailing idea is that process is the foundation for quality and effectiveness (profit). The linkage between capability and process create a challenge for defining maturity generally and this was one of the strengths of the Capability Maturity Model (CMM) originally proposed by Carnegie Mellon University. Originally developed for software engineering, the main point of CMM is the objective evaluation of the "ability to perform" and the model has been applied to many areas beyond technology and engineering. Since its inception in the early 90's, it has become a generalized model for capability maturity. As such, it provides key practices for activities in a given application area that enhance the process capability and subsequent outcome measures in the area of concern(Paulk, Curtis, Chrissis, & Weber, 1993). It is this general nature of capability maturity that allows it to avoid the temporal and finite limitations of the other models, making it suitable for general application.

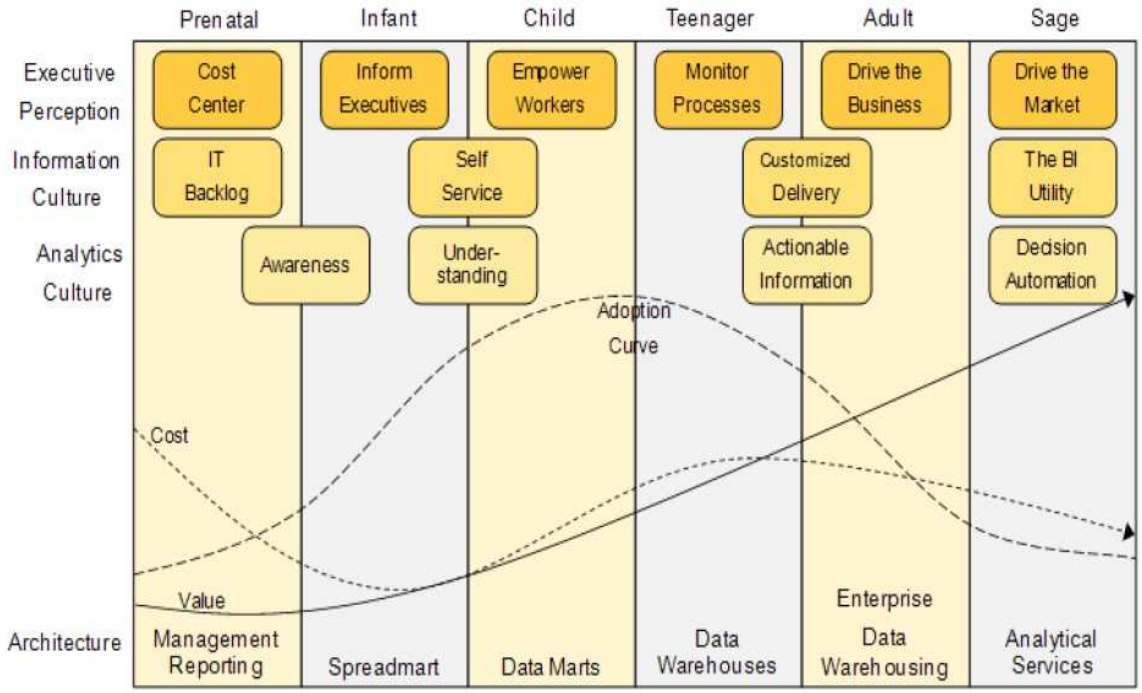

Figure 4: The Data Warehouse Institute's (TDWI) business intelligence model (Eckerson, 2007)

Capability Maturity

The CMMI model is based on 5 levels of maturity that provide indications of process frequency, control, and focus. Table 1, shows the various levels and a description of the nature of each. From this definition, it is clear how the CMM model might be applied generally to a given organization or domain. The specialized nature of BI capability can be grounded in the classifications provided by CMM, but the detailed nature of various BI processes do not allow the CMM levels to be easily extended to a macro scope of business intelligence.

Level	Description
1 – Ad hoc (Chaotic)	Typically undocumented and in a state of dynamic change, tending to be driven in an ad hoc, uncontrolled, and reactive manner by users or events.
2 – Repeatable	Some processes are repeatable, possibly with consistent results. Process discipline is unlikely to be rigorous, but where it exists it may help to ensure that existing processes are maintained during times of stress.
3 – Defined	Sets of defined and documented standard processes established and subject to some degree of improvement over time. These (as-is) standard processes are in place and used to establish consistency of process performance.
4 – Managed	Using process metrics, management can effectively control the actual process. In particular, management can identify ways to adjust and adapt the process to particular projects without measurable losses of quality or deviations from specifications.
5 – Optimizing	Focus is on continually improving process performance through both incremental and innovative technological changes/improvements.

Table 1: CMM Levels (Software Engineering Institute, 2002)

The CMMI capability maturity model can be applied and generally cast to business intelligence maturity. However given the broad nature of business intelligence functionality, the CMM levels occur within the scope of a given industry maturity phase. For example, there were many organizations that were mature in the context of management reporting before the emergence of spreadsheets. Similarly, many organizations had a high degree of sophistication with spreadsheets before

adopting data marts or warehouses. This cycle of immaturity-maturity-immaturity is more characteristic of broad domains like business intelligence.

Evolution and Maturity

The nature of an organization's existence in the context of time often cause many, particularly technology-oriented, initiatives to be undertaken as a function of necessity, implication, or even serendipity (Kaplan & Tripsas, 2008). This provides some anecdotal evidence that capabilities evolve. The biological definition of evolution asserts that all living things have developed from some common ancestor through a long series of natural changes (Bowler, 1989). Defined generally and broadly, evolution is a gradual process in which something changes into a different and more complex or better form. Consider the definition of maturity as "fully developed" or at a state of being ready. When viewed from the perspective of these definitions, it would suggest that BI maturity models are mislabeled evolutionary models. At what point is business intelligence or any such similar technology fully developed?

Business intelligence did not just appear overnight, as perhaps the age of the BI moniker might imply. If maturity is considered as a function of time, then business intelligence has existed since the inception of the first business and is simply in a later stage of maturity. BI took a different form in the first businesses; likely being manually implemented and based on oratory or observable data, but the concepts and functionality that define BI existed. As organizations became more sophisticated, business intelligence began to take on different and more complicated forms; increasingly being linked to computational capabilities. As people and technology changed so did business intelligence – all evolved. This implies that a larger context exists for business intelligence. This raises an interesting research question: if BI is a function that matures, then what exists beyond maturity?

CONCEPTUAL MODEL

The proposed conceptual model suggests that BI does not mature; rather it evolves, driven by internal and external stimuli forcing significant jumps in capability. Maturity is what happens within each evolutionary phase. To use a biological analogy, consider the long-term development of an animal. A species has several iterations of maturation as it traverses the evolutionary path through time. As the animal moves along the evolutionary path there are external factors that cause evolutionary leaps, or even branches that begin a new evolutionary phase. When the macro view of evolution is taken, a path somewhat different than maturity emerges. Consider the conceptual model (Figure 5).

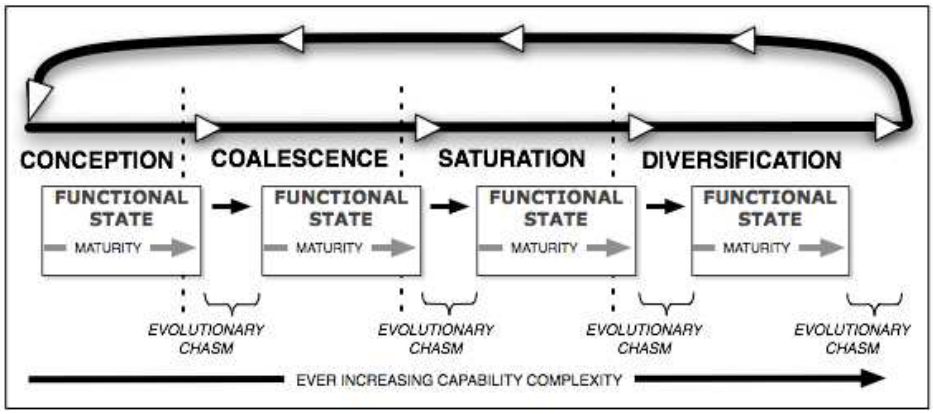

Figure 5: A generalized evolutionary model

The heavy circular line at the top of the model represents the evolutionary path. The evolutionary phases consist of conception, coalescence, saturation and diversification. The contextual object (the thing that is evolving) exists in functional states within the evolutionary cycle, often overlapping phases. Maturation occurs within each functional state, going from ad hoc, to repeatable, to defined, managed, and optimizing; resetting when a new functional state is reached. Exclusive of the contextual object's level of maturity, the object may bridge an evolutionary chasm where it would have been impacted (made to evolve) by some internal or external factor(s). At the end of the evolutionary cycle, conception begins again -- building on the diversity of the last phase. Throughout each evolutionary phase, capability complexity increases and does not decrease even when the cycle begins with a new conception. The conceptual model implies a temporal scale with the evolutionary phases existing on a macro level and the functional states framing the micro level, where capability maturity would be most applicable.

Using a biological example to gain a high level orientation on the conceptual model, consider the evolution of life. Originally beginning as a single cell organism (conception), individual cells eventually developed into multi-cellular forms (coalescence). After which the multi-cellular forms expanded (saturation) and became widely different (diversification); each of those branches began their own path, repeating the cycle, albeit in different ways. BI conceptually would follow a similar orientation, taking on different forms and capabilities as evolutionary changes occurred. The generalized conceptual model is applied to business intelligence (Figure 6), further illustrating a natural progression.

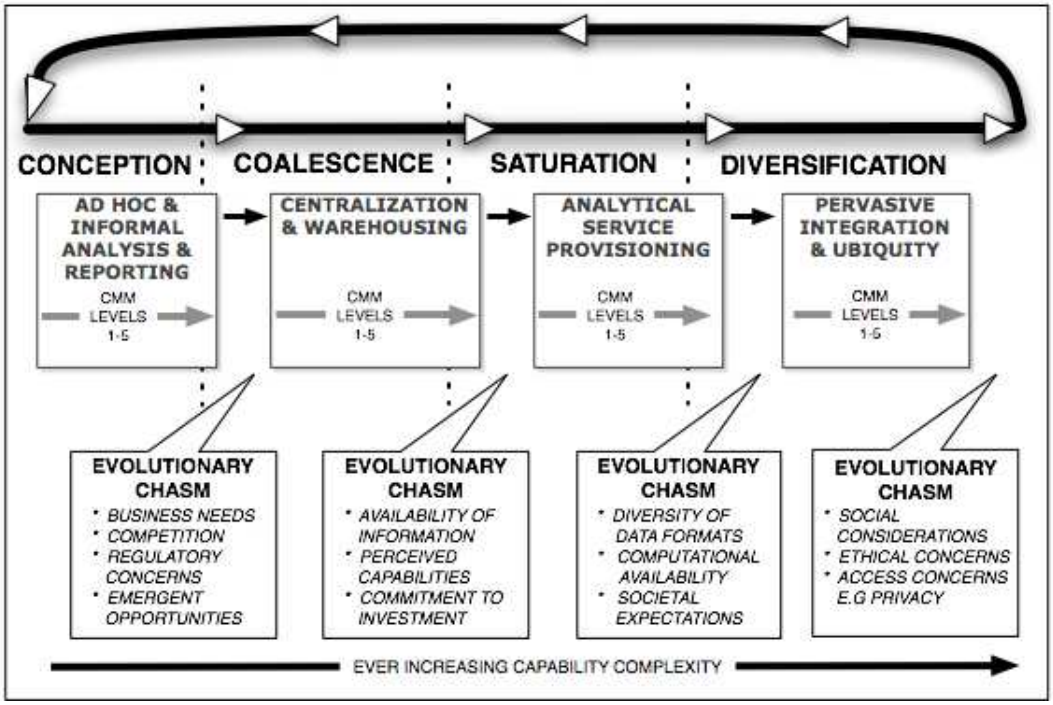

Figure 6: Organic evolution of business intelligence

Significant business intelligence capabilities are cast in the context of the 4 evolutionary phases. At conception, business intelligence is loosely structured. In coalescence the focus is on consolidation and centralization, characterized by the development of data warehousing. With a developed and stable centrally organized repository, the emphasis of business intelligence shifts towards analytical service provisioning – saturating the organization with BI capability. Eventually BI is pervasively interwoven into the organization and is ubiquitous. The accomplishment of ubiquity implies a significant amount of diversity to accommodate the varied environments and applications. Beyond diversification the evolutionary cycle would restart (and potentially branching), resulting from the diversification.

Achieving each of these functional capabilities is dependent on maturity that follows the general CMM tenets described by levels 1-5. In the context of each functional state, heroic efforts are needed; risk and waste may be high, individual initiative is necessary (CMM Levels 1 and 2); institutional processes are developed, implemented, and managed (Levels 3 and 4); ideally reaching a state of continuous improvement in that functional state (CMM Level 5) – setting the stage for driving another evolutionary phase shift. Figure 6 also provides some example evolutionary drivers that must be faced before significant evolutionary shifts are accomplished. These examples are not comprehensive and are intended to merely suggest drivers that may have a significant impact that would mandate an evolutionary shift. Literature has shown that these factors are often considerations for advancing various phases of business intelligence sophistication (Elbashir, Collier, & Davern, 2008; Moss & Atre, 2003; Watson, 2009). However, from a general perspective these factors may be of varying natures, including internal or external technological innovations, regulatory changes, or organizational/societal changes.

ILLUSTRATING THE MODEL: A REAL-WORLD EXAMPLE

The proposed conceptual model is illustrated through the evolution of business intelligence at a large national non-profit organization. Descriptive qualitative data was gathered from a national non-profit organization (Org-A) providing details of the organization's BI inception, implementation, and development to its current day operation. Characteristics of the

organizational activities related to BI are examined and compared to those of the conceptual model and the levels in the CMM maturity.

The Conception Phase

Org-A's BI Conception Phase started with the acquisition of off-the-shelf tools to meet a demand for improved information diversity and reporting. This need was initially triggered by the sales and marketing department targeting the characterization of Org-A's membership. The descriptions provided of this need by Org-A, were indicative of the organization's shift from a relatively stable (characteristic of later CMM levels), if not ideal, management of information processing to an new idea that pushed the envelope of existing capabilities (entering Conception). At the outset of this evolutionary phase, the BI capability at this stage was loosely structured based on producing needed reports in a reactive ad-hoc manner. Org-A progressed by acquiring extract-transform-and-load (ETL) tools, layered on a basic 4-tier BI interface application. Org-A description characterized this effort as chaotic and moving towards repeatable processes to develop defined set of reports to meet sales' and marketing's need (CMM levels 1-3). The end result of the effort was a set of hard-coded/canned reports that met the basic requirements but left room for improvement (CMM level 4). For performance reasons, reports could only be run at night and it was difficult to make changes to the reports themselves. However the process was repeatable, metrics were being gathered on it performance, and the reporting process was defined and controlled, further indicative of Level 4/5 maturity. To improve performance capabilities it was necessary to undertake a significant challenge, one that would likely signal an evolutionary shift and return Org-A to the characteristics of level-1 maturity.

The Coalescence Phase

The problems encountered in the Conception phase provided a focal point for Org-A's stakeholders and a platform had been created on which to extend the technology. With management and end users coming together, the technology needed to do that same to support additional capabilities. The internal IT department was asked to quickly set up a new database that could support on-the-fly (as opposed to static) reporting. This was done through the replication of the data the current system into a new database (the precursor of a formal data warehouse). Replicating the initial schema and leveraging it for read operations was the fastest way to productize reports but certainly the least effective in terms of report response time and report manipulation support: adding and removing data elements for a report was basically not possible because of poor performance. Furthermore, no enforcement of data integrity rules and data quality was put in place resulting in inaccurate reporting (CMM level 1-2 characteristics). However with the availability of the information and the perceived usefulness of BI, the Finance and Accounting management decided to leverage the BI system (further coalescence, but additional CMM level 1-2 maturity). The information technology staff created and deployed the additional static reports, by adding the accounting and finance data from finance ERP systems into what was beginning to be a data warehouse. As the volume of data and the number of users were growing, the BI system performance was degrading mandating the need for a formal data warehouse.

With the development of the data warehouse, which by definition mandated a progression from CMM level 1 to at least 4 (Marco, 2002), all the existing BI reports were re-designed to a new schema (CMM level 3). The schema migration was a high-risk challenging project because over 200 existing reports and many new requests had to be supported during the migration, which meant that 2 discrete development and production environments had to be maintained (characteristic of CMM level 4). The transition was transparent for the BI end users who simply noticed improved performance and capability, as their reports were moved to the new environment (further indication of level 4/5 maturity). With the Org-A operating at a level 4+ maturity with regard to existing BI capability and a newly developed data warehouse, the focus changed from foundational development to exploitation of the existing capability.

The Saturation Phase

The entry to this phase was marked by more emphasis on analytical services and capabilities made possible with a stable and centralized access to the data warehouse. The Saturation Phase my be share activities that are similar to those in the Coalescence Phase, but the emphasis would not be on the initial coming together, more the total inclusion. Total inclusion brought a new set of challenges again resetting Org-A to level 1 maturity. As more applications were added to the BI environment, such as human resources and advertising analytics, the BI system and warehouse were under increased scalability stress (increasing quantities of users and report complexity). To continue the BI expansion, Org-A's newly formed BI group (different form the original IT department) reacted to the rapidly changing environment as best they were able, despite the need for new technology platforms (CMM level 1 maturity). The BI staff's primary focus was on delivering BI capabilities and benefits as a service.

To expand the BI capabilities and meet service expectations (e.g. user self service, machine learning-based knowledge discovery, etc.), the BI staff determined a need to completely overhaul the BI existing infrastructure and upgrade the data warehouse. In early 2009 a Proof of Concept was performed to evaluate the transition from a standard data warehouse environment to an appliance-based solution. This approach promised increased reliability, reduced maintenance, and greater performance. The implementation of this appliance-based solution is currently underway and Org-A is progressing through maturity levels 2-3 with regard to the appliance-based platform. While the new implementation is going on, Org-A's BI staff still has to maintain, deliver, and expand the level of service provided when they entered the Saturation Phase.

The Diversification Phase

Org-A has not yet entered the Diversification Phase, as they are still maturing within the Saturation Phase. Once the appliance-based BI application is in place, Org-A has already made clear where their intentions are in terms of the technology: self-service. Org-A intends to push the BI capabilities out to the desktop so users can create their own BI solutions. Second generation BI tools promise to provide advantages in shortening the BI development cycle, potentially eliminate it, by enabling the BI users to create their own reports without IT or BI staff. Users would be given privileges to directly access the data warehouse and create ad hoc reports and solutions with tools intelligent enough to enable both technical and non-technical users to exploit BI benefits. The initiation of novel technology such with a broad range of user skill levels very likely to return the organization to maturity level 1 or 2 status in this phase. It is equally likely that by exposing BI tools to a diverse range of users, a diverse new range of approaches, solutions, and needs will emerge. The emergent needs will then restart the organic evolutionary cycle with conception around the new ideas.

CONCLUSION

This paper introduces a notion of macro level maturity based on the natural evolution of business intelligence. The proposed conceptual model is examined through the perspective of a real-world BI implementation at a national non-profit organization. The real-world organization illustrates how the model's concepts align with the sequenced activities of a business intelligence implementation and operation of a multi year time frame. The qualitative nature of this research serves to demonstrate how the conceptual model could apply and provide a basis for the exploration of organic macro-level contexts of capability maturity. While this work does not provide a quantitative evaluation of the proposed model, the research's contribution is seen in the introduction of a higher order maturity that may exist and has not yet been the focus of other research efforts.

While a reasonable first step, the exploratory and qualitative examination of the conceptual model prevents any claims of broad generalizability. Further research is necessary to quantify the validity of the model. Models of this nature and in this domain generally suffer from empirical and quantitative evaluation limitations. For example, Bach (1994) notes, that CMM is often criticized as lacking of a formal theoretical basis and on the basis that the models are based on the experience of "very knowledgeable people." As mentioned earlier, maturity models are frequently based on practical industry experience/perspectives rather than having their roots in academic literature. However, there is ample evidence maturity models brings value where there are no other reasonable alternatives and from a practical perspective, they help assess the current and desired state and can serve as communication and change management tools (Andersen & Henriksen, 2006; Herbsleb, Zubrow, Goldenson, Hayes, & Paulk, 1997)

Despite these limitations, the proposed model may find mathematical and theoretical grounding in chaos theory concepts, such as those introduced by Prigogine's (1996) work stating that any open system (of which BI could be considered) will evolve in large shifts, going through a chaotic period before a new level of capability is reached. In this line of thinking, it is noteworthy to mention the Law of Increasing Entropy, which states that all things tend, over time, to break down and become less ordered - unless energy is added in some way. Systems that maintain their orderliness instead of breaking down, or even becoming more ordered, do so because they (or the people that support them) have or create ways to reduce entropy. However any system's ability to dissipate entropy has a maximum upper limit that depends on the system's degree of complexity. These concepts may seem a bit out of place in the context of organic BI evolution and maturity, yet they may provide the theoretical grounding for the conceptual model proposed in this paper. Future work is planned to explore quantitative validation of the conceptual model with a rigorous empirical study. Additionally, a study is planned that will examine the feasibility of constructing a mathematical model that incorporates system complexity and entropy in the context of maturity and evolution.

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